# LOW NOISE PROP-FAN

## BACKGROUND OF THE INVENTION

This invention relates to high bypass, variable or fixed pitch, ducted propulsion fans having downstream stator vanes and no upstream vanes hereinafter referred to as prop-fans and particularly to means for reducing the noise level generated by the fan/stator combination.

Bypass engines with many-bladed, fixed pitch fans, as for example, the 5:1 bypass JT9D engine manufactured by Pratt & Whitney Aircraft or the 6:1 bypass TF-34 engine manufactured by General Electric, exemplify the current state-of-the-art in propulsion air fans. These fans operate at fan pressure ratios of 1.4 to 1.5 and, at these loadings, require high blade solidity and must rotate at high tip speeds to achieve good performance. Consequently, such fans are known to be characterized by inherently high levels of noise generation. It is also well known in the art that to attain somewhat more acceptable noise levels, particularly when installed in commercial transport aircraft, these fans require extensive use of noise reducing devices such as long shrouds with noise absorptive liners and rings. Such noise abatement techniques have proven quite costly particularly in terms of added weight and loss in aircraft performance.

I have discovered that I can obviate the problems noted above while obtaining installed noise levels that are lower than those heretofore obtained, by operating the prop-fan within a unique range of fan pressure ratios and tip speeds which range lies between the operational points that are usual in propellers and fan engines.

Not only does my invention afford a reduction in noise levels not attainable in heretofore known propellers and fan engines, but afford better takeoff performance than heretofore obtained by conventional bypass engines while incurring less penalties in weight and no compromise in cruise performance. Prior to this invention it had been understood by those considered skilled in this art that a modest noise reduction from that of present fan engines could be realized by reducing fan pressure ratio and consequently fan tip speed. For example some work of this trend has been evidenced in publications regarding the Astafan engine manufactured in France and the Dowty-Rotol fans manufactured in England. Additionally U.S. Pat. No. 3,489,338 granted to J. A. Chilman on Jan. 13, 1970 exemplifies the current state of the art. There had been neither prior recognition nor suggestion, however, that a prop-fan operating in this intermediate pressure ratio range and at subsonic tip speed would result in much larger noise reductions when the fan/stator combination was designed in a specific aerodynamic configuration.

In accordance with this invention, I have found that the sources of fan/stator noise generation in this intermediate range of fan pressure ratios are governed by a new set of acoustic phenomena, quite different from that taught by the prior art. The critical range of fan pressure ratios for the prop-fan is between 1.05 and less than 1.30. In this range it is possible to design aerodynamically efficient fans with a moderate number of blades (6-13) and low tip speeds (600-800 ft/sec. or higher but less than sonic). It is this unique combination of fan blade count and tip speed that puts the prop-fan in a new range of acoustic frequency spectra and that radically alters the acoustic phenomena governing its noise generation.

By virtue of a study of these phenomena it was found that, unlike the prior high pressure ratio, high tip speed fans whose noise spectra were rotor dominated, the noise generated by the prop-fan, operating in this unique range of variables, would have a noise spectrum which would be stator dominated. Thus, the well established practices embodied in the teachings of the prior acoustic art, which called for the use of substantially twice the number of stator vanes as the number of rotor blades, would not be appropriate for the prop-fan. Although this prior art concept has been demonstrated to effectively reduce noise of the highly loaded, supersonic tip speed fans by suppressing some of their rotor-dominated noise frequencies, these rotor noise sources are not dominant in the prop-fan noise spectra.

With this new understanding of the acoustic phenomena of the prop-fan, I have found that the most effective means for reducing its noise signature is to use a completely new set of criteria which is contrary to the well established heretofore known criteria. The principal element of these new criteria is to have the number of stator vanes be substantially one half that of the rotor blade count instead of increasing the number of stator vanes to have a greater number than rotor blades as would be suggested by the prior art. This serves to suppress the critical stator-dominated noise frequencies in the prop-fan spectrum.

There is a further benefit of the reduced frequencies in the prop-fan spectrum which relates to the subjective response of the human ear to different frequency levels. The human ear is most sensitive to frequencies in the range of 2,500 to 5,500 Hertz. Accordingly, another important element of this invention is the unique combination of fan blade count and tip speed, previously defined, which puts the critical acoustic modes of the prop-fan well below this range. This is illustrated by the test results plotted in FIG. 1 in comparison with the noise spectra of prior types of turbofans. As a result, the prop-fan not only generates low noise energy by virtue of its reduced number of stator vanes, but the positioning of the principal acoustic modes below the sensitive frequency range results in an additional substantial reduction in perceived noise level.

There are several other criteria which are also novel and constitute a significant contribution to this invention when combined with the above described new concept. One is the use of variable pitch on the rotor blades for minimizing noise generation at off-design conditions such as at takeoff. Since the prop-fan noise generation is dominated by stator sources it is important that the periodic pressure pulses emanating from the rotor be minimized prior to their impingement on the downstream stator vanes. With variable pitch on the rotor blades, they will operate at more optimum aerodynamic angles at such off-design conditions, and thus generate weaker pressure pulses. This will serve to further suppress the stator originated noise modes. The relatively few fan blades of the prop-fan compared to prior art fans makes the mechanical implementation of variable pitch more feasible.

Another means of achieving a similar effect is to increase the linear separation between the downstream stator and the rotor. From a detailed understanding of the aerodynamic behavior of the pressure pulses shed